Urgent Interactions: Evaluating Usability and Incorporating Information Visualization in Emergency Medicine Interfaces

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ABSTRACT
Development of information systems for the healthcare sector has been a rapidly growing area in recent years; however, little attention has been placed on the need to improve usability for the physicians who use these interfaces, and little research has been done on incorporating information visualization techniques to aid the complex data analysis involved in charting and evaluating medical records. This paper presents research conducted in a hospital emergency department to identify usability issues in the Tracking Board and an EMR. A comprehensive list of design issues was derived through contextual inquiry sessions and problem report diaries from physicians. Recommendations for redesign of the Tracking Board screen were developed and are illustrated in a prototype developed partly through participatory design; conceptual ideas for the redesign of EMRs are also presented. The paper concludes with an evaluation of the value of the presented recommendations as well as the value of employing information visualization in emergency department information systems and elucidates areas of focus for future research.

KEY WORDS
Patient tracking systems, Electronic Medical Record (EMR), Information visualization (IV), Emergency department interface, Healthcare IT, HCI

1. INTRODUCTION
Healthcare Information Technology and Electronic Medical Record (EMR) systems have received a great deal of attention in the technology and healthcare industries in recent years, particularly due to government reimbursement plans meant to encourage their implementation nationwide by 2014. Software developers everywhere are vying for large contracts with hospitals and their affiliates. In creating these kinds of systems, developers have placed a great deal of emphasis on issues and attributes like synchronization, interoperability integration, and productivity. However, in the development of these types of products, there has been much less focus on usability for the doctors and medical staff that must directly interact with patient data and records. For physicians, the utility of being able to easily and quickly input, track, and retrieve patient data cannot be emphasized enough, particularly given the urgency and gravity of decisions made in an emergency department setting.

The purpose of this paper is to draw focus to the types of usability issues commonly encountered in emergency department interfaces that are already in use today to investigate how they might be improved in future iterations and redesigns of such software by applying basic HCI principles. Issues affecting the usefulness, efficiency, effectiveness, learnability, accessibility, and general satisfaction of the physician user were uncovered and analyzed, and design recommendations are provided. As a secondary goal, this paper seeks to consider the possibilities for information visualization techniques in aiding information overview and comprehension of patient data and records. Information visualization techniques have been utilized to great result in other fields requiring analysis of complex data, yet have remained understudied and underutilized in the medical realm. This part of the research entailed a general investigation into how doctors make sense of the myriad data that comprise a patient’s history to see how they determine which information is pertinent and useful in a time-limited situation. Basic techniques in information visualization were researched and possibilities for how their implementation in medical interfaces could possibly improve usability and efficiency in understanding the record are suggested.

At the start of this research, the aim was to do somewhat comprehensive analysis of patient tracking, charting, and accessing information in medical records. However, as field research progressed, the breadth and depth of issues identified grew seemingly exponentially, and thus the scope was narrowed to a more specific focus of evaluating the one-screen Tracking Board and a one-screen EMR from the interface of an emergency medicine department at a large suburban hospital.

These two screens were chosen for multiple reasons. First, neither screen requires input to provide utility, which made focusing on them a more feasible endeavor. Symptom input and charting screens are highly complex and require a great deal of manipulation, and thus would need to be studied in a project with a larger scope. Secondly, these two screens play an important role in decision making for their physician users, thus comprehension of information on these screens and their usability are of the utmost importance. By contrast, in the contextual inquiry phase, it was discovered that number of the symptom entry and charting screens investigated early on in the research were actually mostly for billing purposes and did little to aid patient treatment. And finally, the design of the two screens are almost diametrically opposed; the Tracking Board screen puts visual elements to almost excessive use, while the EMR screen is completely textual, employing no visual design techniques whatsoever. The contrast between these two screens provides an interesting basis for evaluating and comparing the use of visual elements and jumping off point for discussing information visualization techniques and how they might be employed in emergency department information systems in the future.
2. RELATED WORK
Despite the usability problems still encountered in real-world applications of health information systems, volumes have been dedicated specifically to promoting usability in this field. The research conducted for this paper uses general HCI principles and heuristics to evaluate a healthcare interface, and data was collected through very low-tech methods. More information about specific, high-tech approaches for evaluating usability in health information systems can be gleaned from [5], which includes discussion of the creation of a virtual usability lab designed for a priori testing of medical interfaces.

There is also an overwhelming body of work that has been done on the topic of information visualization (IV), explaining ways in which it might be employed and touting its benefits, such as making complex information easier to understand and manage, making subtle aspects easier to notice, and preventing information overload. IV has its roots in understandings of perception of representations and cognition of information for problem solving, which are discussed in great detail in [3, 6]. Common types of data displayed include linear data, planar and map data, volume data, temporal data, multi-dimensional data, tree data and network data, and common tasks include gaining overviews, zooming, filtering, getting details, viewing relationships, exploring histories, and extracting sub-collections. [12] Other basic explanations of IV and its applications can be found in [4, 15].

There has also been some work in IV specifically focused within the field of healthcare information system and EMRs. Much of the work focused on IV in EMRs relates to the display of temporal data in a patient’s personal history and how visualization techniques can be used to reveal hidden patterns and important cause-and-effect links. [14] Some of the research illustrates how IV can be used to enhance navigation and analysis of patient records. One such example, LifeLines, illustrates how an IV tool can act as a giant menu, providing direct access to data needed to understand patient problems, diagnoses, test results or medications. [11] A more general overview of IV applications within the medical field can be found in [2]. There has been very little work that specifically reflects upon the use or potential use of IV in an emergency department setting.

3. APPROACH
3.1 Participants and Setting
The main participants throughout the research process were three physicians who work in the emergency department of a large suburban Chicago hospital. All three have been out of residency for over seven years, but less than ten, and all have been using the system at the observed hospital for over one year. Additionally, all three have been using computerized charts their entire careers as attending physicians and have little experience with paper charting. All the physicians in the emergency department rotate through various shift cycles including morning, day, evening, and night shifts. Data was collected in each of these various shifts.

The hospital itself is quite large with a number of affiliate groups; the emergency department in particular is a busy, 40-bed Level II trauma center that typically has 25 or more patients at any one time. The environment in which the physicians work has an important impact on interactions with the interface they use. The computer bank where the physicians conduct their data-entry is centrally located in the department at a large counter by the nurses’ station. The area is open and heavily trafficked by doctors, nurses, physician assistants, cleaning staff, orderlies, and others. Background noise levels are loud and sound travels widely. This noise, combined with the continuous movement of people through the space, provides a distracting background against which physicians must focus their attention and complete very complex tasks. Added to the noise and background distractions are the actual interruptions which require the physicians’ attention.

This chaotic environment impacts how an interface must function in several important ways. First, it completely affects time on task. After each interruption, the physician must locate the place he had last left off in the interaction process, reentering from a login screen if the interruption lasts more than one minute. Secondly, the environment competes for attention throughout any task. An item needing attention must be that much more salient to grab the user’s attention from the surrounding noises and actions. And finally, it impacts memory. Because most data is entered straight from memory, the noise and other distractions can cause the user to lose track of or forget certain pieces of information or lose focus. For these reasons, evaluating the emergency department environment was an important aspect in data collection.

It is also important to note that physicians have developed ways to cope with many of the issues encountered during data collection through repeated experience in dealing with the issues in every shift. It is important to remember, however, that physicians, while experts at their job of patient care, are not necessarily experts with the system they use to track, input, and retrieve patient data. In the emergency medicine field in particular, physicians often work shifts at different hospitals using very different information systems. Additionally, because symptoms, diagnosis, and treatment of patients in emergency departments range the entire spectrum of healthcare, they frequently utilize different aspects of the interface, making it more difficult to become an “expert.” For example, a physician may not remember a field labeled with a specific abbreviation because he has not entered data for a patient with those conditions in some time.

3.2 Data Collection
Data collection began with a more general focus of evaluating a segment of the system used for patient data in an emergency department, but as the scope narrowed, the goals of analyzing the usability of the Tracking Board and a basic page from an EMR came into focus. The following questions became the focus for data collection:
• How usable and efficient is the current Tracking Board interface? What are the major pain points and problem areas?
• How easy or difficult to comprehend and synthesize are EMRs, particularly in an urgent or time-condensed situation?
• How can the design of these two screens be improved through HCI principles?
• How can information visualization techniques be used to aid in these tasks?
To investigate these areas, data was collected in the emergency department setting through contextual inquiry sessions and problem report diaries.

3.2.1 Contextual Inquiry Sessions
A total of six contextual inquiry sessions were conducted during various shifts with two different physicians. Each session lasted anywhere from one to two hours and occurred entirely at the physicians’ computer bank. The initial sessions helped to identify the major pain points and problems with the current interface in order to determine which areas of the interface were feasible for further investigation. Five screens with major problem areas were initially identified for further focus and evaluation. The scope was eventually narrowed to a more feasible set, focusing on the Tracking Board and a basic EMR encounter page (meaning a record from one hospital visit). There are number of complex
elements included in the EMR system; for the purposes of this research, only a section of a single record is the focus.

Segments of some of the sessions were recorded and screenshots were taken for analysis. Open discussion and inquiry occurred throughout the sessions. Nurses and patient care technicians also participated in discussion and shared information and opinions. Additionally, physicians answered some questions through email and phone conversations between sessions.

3.1.2 Problem Report Diaries
Three physicians (the two who participated in the contextual inquiry sessions, plus one additional physician) also helped to collect data outside of the contextual inquiry sessions by maintaining a group diary of issues they encountered while using the interface. These problem report diaries consisted of writing brief notes on a notepad by the computer after their shift during a four week period. On the handwritten log, the participants noted the date, the screen on which the issue occurred and the problem encountered, and, if possible, how it affected their work or patient care. As the scope narrowed, the participants were asked to focus primarily on the Tracking Board screen and EMR interface. A total of 14 additional issues not uncovered in the contextual inquiry sessions were identified through this process and are included within the grouped issues in the following section. In total, there were over 40 issues collected from the log, but many had been either previously noted in the sessions or remained outside of the scope of the study. These issues were discussed more in-depth in email and phone conversations after the logs were collected.

3.3 Recommendations, Prototype Development, and Participatory Design
With the data gleaned from the contextual inquiry sessions and problem report diaries, problem areas were identified, categorized, and delineated. Using a combination of heuristics and guidelines from research sources and general HCI principles, design recommendations were developed to address the issues.

From these recommendations and principles, a basic non-functioning prototype of the Tracking Board was created. This prototype then served as the basis for discussion and evaluation in a participatory design exercise with the two physicians who participated in the contextual inquiry sessions. Additionally, conceptual ideas for the redesign of a single page EMR incorporating IV were developed and evaluated in this session.

In the participatory design session, the physicians gave their feedback on the design of the Tracking Board prototype and their general impressions of the conceptual ideas for IV in EMR’s. Because physicians go through certain mental processes and procedures when evaluating the tracking board or patient data in an EMR, this session allowed for the draft redesign to be assessed on this basis. They were asked questions to provoke thoughts for revisions. The physicians sketched out their ideas for design changes that would be more intuitive to them and would assist in the mental processes they go through when using the system. Several of the ideas derived from this participatory design session were incorporated into a new iteration of prototype for the Tracking Board as well as the conceptual ideas for IV in EMR’s.

4. TRACKING BOARD
4.1 Usability Issues and Design Problems
The contextual inquiry sessions and the diaries aided in identifying a number of problems with the Tracking Board from the point of view of the physicians. It should be noted that the Tracking Board is set up for a variety of different views, depending on the user who is viewing it; only the physician view was analyzed.

The following subsections indicate categories of issues identified during data collection. The categories include: perceptual and attention issues; learning and memory issues; information availability issues; and interaction issues. Within each category, more specific sub-subsections address clusters of problems. Problem areas are illustrated within Figure 1, the Tracking Board and are also listed in Table 1: Tracking Board Issues and Recommendations.

4.1.1 Perceptual and Attention Issues
In general, seeing and correctly identifying visual information on the Tracking Board was one of the most important categories of problems observed. Areas of difficulty related generally to the following: contrast ratios; color reliance; contrast with neighboring elements; discriminability; and motion and attention.

4.1.1.1 Contrast Ratios
Highlight and background colors are used frequently within the Tracking Board interface. For small text, contrast ratios below 7:1 are hard to read. The Team 3 highlight color is navy blue over black text, which has a contrast ratio of approximately 1:1, making it almost impossible to read. Spatial frequency has an impact on this, because the closer the lines, the harder it is to see text. So, more contrast is needed for small text.

4.1.1.2 Color Reliance
Red is used frequently as a highlight color, and green is used as well. This single reliance on color affects those with deuteranopia or protanopia (red/green color deficits). Additionally, various shades of blue and yellow are used, adversely affecting anyone with tritanopia (blue/yellow color deficit).

4.1.1.3 Contrast with Neighboring Elements
Alternating columns are not distinguished by lines or shading, making it difficult to follow one line all the way across. This also affects attention because individual columns exhibit behaviors to grab attention (blinking, color highlights), but since this is not distinguished the row of information needing attention does not “pop.” [9]

4.1.1.4 Discriminability
Some elements within the Tracking Board are very similar, despite intending to represent different things. For example, in the RAD column (radiology results), an asterisk next to the “Y” is the only thing indicating a new result has arrived. The discriminability, or ratio of similarity to dissimilarity when scanning the column, is low, which can cause confusion and lead to it being overlooked. [13]

4.1.1.5 Motion and Attention
Blinking is utilized in the interface in multiple ways. In one instance, a blinking yellow highlight can mean a patient needs to be discharged. In another case, blinking indicates an infectious alert. Often times, there will be multiple items blinking on screen at one time, distracting the user’s attention.

4.1.2 Learning and Memory Issues
Even when objects grabbed attention and were perceived properly, several issues affected the ability for those elements to be understood. These comprehension failures were repeatedly identified as a major source of frustration during the contextual inquiry sessions. Physicians often could not answer questions as
to what something on the screen was intended to represent because they had either never learned what it meant or could not remember. General problem areas related to categorization and a lack of pedagogic and reference tools.

4.1.2.1 Color Categories
The Tracking Board utilizes a number of highlight colors, making it difficult for physicians to judge the meaning of each hue because there are more than 7 possible hues. [8] The Tracking Board can display at least 10 highlight colors, so it is hard to remember what a particular hue means.

Compounding this problem is the fact that several colors are used to represent completely different things. For example, the same red hue is used for at least five different purposes identified in the Tracking Board. A red highlight may indicate that a user has a new patient. It also may indicate a “To do” item for a nurse in the second RN column. A blinking red highlight in the IA column indicates an infectious alert, such as an alert that a patient has MRSA (methicillin-resistant Staphylococcus aureus). Red can also represent patient allergies. And finally, red highlights are also used in the REG column to indicate a “QR,” which means the patient has not yet been fully registered in the system and cannot be discharged due to billing requirements. Additionally, when a physician clicks into a chart to see lab results, red indicates abnormal results within that page. Because colors are frequently activated for completely different purposes, there is a great deal of ambiguity as to what a color means at any one occurrence.

4.1.2.2 Pedagogic Tools
There is a dearth of tools available to help users learn and remember what things mean, like pedagogic vectors or tooltips. If a user forgets what a color, symbol, or abbreviation mean, he typically must seek help from a colleague to find the answer.

4.1.3 Information Availability Issues
While not identified as a major pain point, information availability was noted multiple times as a problem that led to clicking into other areas of the interface to find the information needed at any one time. Additionally, the lack of ability to customize the information view created some issues.

4.1.3.1 Categorization
Categories should be defined by their purpose. [1] A number of information categories are provided in the Tracking Board, but not all are very helpful. Categories such as LOC (location, which is not useful since the bed number is already indicated), RT (Respiratory Therapy, which is rarely used), and MOA (mode of arrival) are infrequently used and have no goal-oriented purpose in the Tracking Board.

Additionally, several categories of information that would be quite useful to medical staff are not included in the tracking board. Examples of purposeful categories not included are: indicators as to which orders have been carried out, so that the doctor can see where they are in the process of carrying out tests and orders; the primary care physician of the patient, which would help in order to contact the doctor for immediate background information; and how many radiology orders are in line ahead of a particular patient’s, to indicate how long the wait will be.

Finally, categories that are related are not necessarily next to each other in the display. For instance, the two RN categories should be next to each other to relate the nurse assigned to the patient to the tasks he or she is working to complete, but the lack of proximity makes them seem unrelated.

4.1.3.2 Information Views
A physician can limit a view to only the patients to whom he is assigned, or display one or more of the emergency department teams. Within these views, rows can only be sorted by length of stay, bed number, or ESI (severity). There are no other categories by which to sort. As one physician pointed out, it would be quite useful to sort by orders that need to be carried out, so as to prioritize what they need to do next. There is also no way to sort by multiple categories, such as severity first, then orders needed to be completed.

4.1.4 Interaction Issues
The Tracking Board unfortunately provides no way to directly input or manipulate the data contained on the screen. The only way data can be changed, added, or deleted is by clicking through to the chart and inputting it there.

While this was never clearly identified as a problem, since interaction within the Tracking Board is not an expectation, it was nonetheless clearly an impediment in completing certain tasks quickly. For instance, in order to change the status of an order to being done, the user must click into the chart and find the correct area to make the change, even though the status indication is only needed on the Tracking Board. Clearly, the Tracking Board is being underutilized for this sort of task. Accelerators, context menus and free text manipulation are not available, but could add a far more convenient way to quickly complete tasks within the Tracking Board screen.

4.2 Recommendations
In general, changes should be incorporated to make working with the Tracking Board a low-load task, which is one that requires fewer mental resources. [7] By reducing the mental effort required to recognize, process and act on information in the Tracking Board, more mental capacity can be devoted to other important tasks related to patient care. The following general areas of recommendations address the four main categories of problems above. Recommendations are included in Table 1: Tracking Board Issues and Recommendations, and they are illustrated in Figure 2: Tracking Board Prototype.

4.2.1 Addressing Perceptual and Attention Issues
There are a number of ways to change the Tracking Board interface to address the issues related to perceiving screen elements. First, colored highlights should only be used for redundancy gain, so as not to negatively impact those with color deficit issues, and no more than 5 to 7 hues ought be used in the single screen to avoid absolute judgement limits. Additionally, when highlights are employed, the contrast ratio should be at least 7:1. Instead of colors, icons or shapes could potentially be used for some column categories. These distinct icons or characters should be used to highlight differences, such as when a new lab result is available. Blinking or motion should only be employed when immediate attention is needed for something urgent, rather than for every discharge that occurs. And finally, rows of information should be clearly separated and grouped information should alternate background shading in order to create contrast from neighboring groups, such as the information grouped by physician.

4.2.2 Addressing Learning and Memory Issues
To avoid absolute judgement limits, a maximum of seven colors should be used to represent a status; additionally, each color should only represent one status or message, not multiple. Pedagogical tools such as tooltips and pedagogical vectors (icons next to text) could be utilized in the interface to help reduce memory load and aid in learning.
### Table 1: Tracking Board Issues and Recommendations

<table>
<thead>
<tr>
<th>Section #</th>
<th>Problem Area</th>
<th>Example</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.1.1</td>
<td>Perceptual and Attention Issues</td>
<td>Bottom of column 1 has a 1:1 contrast ratio</td>
<td>Improve highlight contrast to minimum of 7:1</td>
</tr>
<tr>
<td>4.1.1.2</td>
<td>Color reliance without redundancy</td>
<td>Use of red, green, blue, and yellow highlights affect deuteranopia or protanopia, tritanopia</td>
<td>Highlights should only be used for redundancy gain if necessary, never as sole indicators</td>
</tr>
<tr>
<td>4.1.1.3</td>
<td>Contrast with neighboring elements</td>
<td>Rows and groups of information are not easily distinguishable</td>
<td>Rows of information should be clearly separated and groups alternate background shading</td>
</tr>
<tr>
<td>4.1.1.4</td>
<td>Discriminability</td>
<td>In RAD column (radiology results), an asterisk next to the “Y” indicates a new result has arrived</td>
<td>Use disparate icons or characters to improve ratio of similarity to dissimilarity</td>
</tr>
<tr>
<td>4.1.1.5</td>
<td>Motion and attention</td>
<td>Blinking items, such as yellow “discharge” highlight mean different, unimportant things and distract user</td>
<td>Blinking should only rarely be utilized, for urgent action items that are critical to patient care</td>
</tr>
<tr>
<td>4.1.2.1</td>
<td>Learning and Memory Issues</td>
<td>10+ highlight colors make it difficult to remember meaning; colors are activated for very different purposes (red used 5 ways)</td>
<td>Avoid absolute judgement limits, use a maximum of seven colors with each color representing only one status or message; use distinct symbols</td>
</tr>
<tr>
<td>4.1.2.2</td>
<td>Pedagogic tools</td>
<td>Nothing available to remind user what a color, symbol, or abbreviation means</td>
<td>Add pedagogic vectors to menus, a key to symbols, and tooltips</td>
</tr>
<tr>
<td>4.1.3.1</td>
<td>Information Availability Issues</td>
<td>Some categories (LOC, RT, MOA) have little or no utility; other categories needed, like Primary Physician, are not available; related categories are not collocated</td>
<td>Revise categories available to better meet physician needs; group categories in more intuitive way</td>
</tr>
<tr>
<td>4.1.3.2</td>
<td>Information views</td>
<td>Limited customization to order/sort info</td>
<td>Add multiple ways to prioritize information</td>
</tr>
<tr>
<td>4.1.4</td>
<td>Interaction Issues</td>
<td>No direct manipulation/interactivity avail.</td>
<td>Add accelerators, context menus, free text</td>
</tr>
</tbody>
</table>
4.2.3 Addressing Information Availability Issues

The chart should be revised to exclude infrequently used categories of information and to include much needed ones that provide primary care provider names, statuses of orders, and information to identify approximate times or waits for lab or radiology results. Categories that are related mentally or task-wise should have a close proximity to one another. Additionally, all categories should be activated as a method of sorting.

4.2.4 Addressing Interaction Issues

To improve overall functionality and usefulness of the Tracking Board, there should be input capabilities. Free text fields like those in the Comment column should be able to be directly manipulated from the current screen, and other fields should be able to be manipulated via a right-click action menu that provides accelerators. This menu could provide icons to indicate that results are ready, that orders have been carried out, or that a patient has been registered, etc., so that the physician or healthcare worker can complete that type of notification task without having to enter another screen. This minimizes information access cost, reducing the time needed to complete simple tasks.

4.3 Prototype

A draft prototype was created incorporating the above recommendations and was presented to the physicians during the participatory design and feedback session. The draft version included many of the ideas incorporated in Figure 2: Tracking Board Prototype.

Once the draft prototype was presented to the physicians in the participatory design session, several further refinements came out of this iterative process. The primary area of refinement was in creating a way to increase interactivity of the Tracking Board so as to reduce the need to click into a patient’s chart to accomplish simple tasks. The physicians liked the system that was created for the triage category (Esi column) which incorporated symbols to indicate the resource category/patient severity. In discussing ways to incorporate more interactivity, they noted that quickly ordering common tests, being notified of results, and viewing the results are processes that take up much more time than necessary by requiring the user to click into the chart. They thought that a system of adding symbols for common tests would be an incredibly useful feature.

The physicians quickly identified the most common tests that they would likely order frequently, saying that these seven tests account for upwards of 80% of all tests ordered. They brainstormed a symbol system they felt they would be able to easily identify and remember for the seven tests. For the three most common blood tests they suggested the following: a heart icon for cardiac tests; a lightning bolt for electrolytes; a circle for hemoglobin. For the four most common radiological tests they decided on the following: an X for x-ray; a U for ultrasound; a C for CT scan; and an M for MRI. They suggested using characters for one (radiology tests) and images for the other (blood tests) to make the distinctions clearer and easier to remember.

To make the test information an interactive feature, they suggested the tests be able to be ordered, results indicated, and results viewed directly from the Tracking Board. Working together, it was decided that a contextual menu with action choices would be available by right-clicking on the Test cell for a patient. Through this context menu, physicians would be able to add any of the 7 most common tests. Clicking on a previously ordered test would allow you to see results, if available. Unviewed results would be indicated by a black background around the symbol, while a white background would indicate the available results had already been viewed.

Several other useful suggestions were derived from the participatory design process, particularly focused on ways the Tracking Board could be more interactive and aid memory. Moving forward into a higher-fidelity prototype, more of these ideas could be incorporated into a new Tracking Board design.
5. ELECTRONIC MEDICAL RECORD

5.1 Usability Issues and Design Problems

The following subsections indicate categories of issues identified during data collection. The categories include: referential and temporal relation issues, visual cue problems; record macrostructure issues, and scanability issues. Problems are generally shown in the EMR example in Figure 3: EMR Screen and Figure 4: EMR List.

5.1.1 Referential and Temporal Relation Issues

When a physician enters a patient’s records through the hospital’s portal, they are provided a list of encounters with or visits to the hospital and its affiliates in chronological order (Figure 4). In addition to this organization of visits not being very helpful, the text of the list items does not facilitate strong referential or temporal relations to the record it points to. Individual encounter records are labeled by department, doctor, and date together, giving no indication of diagnosis or result. Thus, a physician may need to click through and scan multiple records before finding one that provides relevant information. In the example list shown in Figure 4, the physician referencing the records was attending to a patient who was encountering breathing issues. In this instance, he only know to click on the fourth record for pertinent information because the name of the physician listed in the Item column was a physician whom he knew to be in the area of pulmonology. Had he not known this, he would have clicked through several more individual records to find information about the patient’s history of breathing troubles.

5.1.2 Lack of Visual Cues

When a physician clicks on an individual record of a patient visit, the page provides no immediate clues as to what the visit entailed or what the end result was. This information is buried deep within the text-heavy page. There are no visual clues to immediately distinguish a surgical procedure from a department consultation. The text itself is all the same font family, font size, weight, and color. One physician noted that when charting, he often writes important free text in caps in order to have a method for determining what was important in the patient’s record, since there are not other ways to manipulate the display of the information.

5.1.3 Scanability Issues

Visual acuity is greatest at the fovea, the center of the retina, where the highest concentration of receptors is located. When reading, the eyes move to focus the input on the fovea, jumping between portions (saccades) and processing text on fixations. Because records vary depending on the symptoms, diagnosis, and treatment of the patient involved, content is not very standardized.
have stronger referential relationships with the records to which relevant information, the EMR transcript list (Figure 4) should To reduce time spent delving into individual records to find Issues

5.2.1 Addressing Referential and Temporal Relation

address some of the identified issues are presented. However, conceptual ideas for how a redesign might begin to treatment, a full redesign was out of the scope of this project. particularly depending on the type visit and patient diagnosis and what the end result was. However, there is no standardization between types of records (an endoscopy as opposed to a radiology report, for example), and no focus on connecting the data between records. This ambiguous structure creates an inability to quickly find content, forcing the physician to dig into one record and then often go back to the record list to dig into another to find the needed information or further details.

5.1.4 Record Macrostructure

The lack of cohesive macrostructure for each encounter’s EMR negatively impacts text comprehension and an understanding of the record in relation to others. There is a general superstructure or genre that indicates that an EMR will contain information about the patient, who did the study, how the study was conducted, and what the end result was. However, there is no standardization of headings, summary statements, and overviews or abstracts are not used advantageously; therefore, techniques to aid scanning should be employed.

5.2 Recommendations and Conceptual Prototypes

In general, changes should be incorporated to make working with the EMR more simplified and comprehensible. Utilizing IV techniques can help to make complex information about symptoms, diagnoses, test results, and medications easier to understand and manage, can make subtle patterns and cause-and-effect links easier to notice, and can prevent information overload. The following recommendations are primarily based on analysis of the EMR using Shneiderman’s task-by-data-type taxonomies [12], which focus on seven types of tasks: overviewing, zooming, filtering, getting details, identifying relationships, keeping a history of actions, and extracting sub-collections of data, and seven types of data: 1-D, 2-D, 3-D, temporal, multi-dimensional, tree, and network.

While the following general areas of recommendations address the four main categories of problems in the section above, there was no comprehensive way to illustrate what a full prototype would look like. Because of the complexity of the EMR, particularly depending on the type visit and patient diagnosis and treatment, a full redesign was out of the scope of this project. However, conceptual ideas for how a redesign might begin to address some of the identified issues are presented.

5.2.1 Addressing Referential and Temporal Relation Issues

To reduce time spent delving into individual records to find relevant information, the EMR transcript list (Figure 4) should have stronger referential relationships with the records to which the list redirects the user. Records should be both titled or described in a way that indicates the diagnosis or result in some significant way and also organized in a way that provides a tree-like data structure.

Figure 5 illustrates how a tree structure might provide an easier way to break down this complex assortment of data. From the participatory design session, it was determined that there were five distinct categories of records an emergency medicine physician may need to view to obtain pertinent patient data. These are, in order of importance: discharge data from any hospital visit; admitted visits to the hospital; past surgeries; past consultations of any specialty; and past emergency department visits. As the tree structure in Figure 5 indicates, these categories could be broken down by patient viewed to provide an overview of the records available, which would be indicated in the second tier by number. Zooming into any of the five categories of interest could provide a breakdown of the focus of individual records, such as pulmonology and cardiology under consultation in the figure.

Once a physician has zoomed to the pertinent area(s) of information, records could be filtered to remove uninteresting results, like a consultation that had no significant findings. From there, an individual record with pertinent information could be selected, and individual records compared by following the same pattern again to identify important records in other categories or subcategories. For instance, records with important cause and effect relationships for a patient who has just been brought in with breathing problems can be more easily and more quickly identified by moving through a task path that identifies more significant hospital visits or surgeries related to lung issues over past emergency department visits that may have been related to something completely arbitrary, like a sprained ankle.

5.2.2 Addressing Lack of Visual Cues and Scanability

Similar to being able to identify a potentially pertinent record quickly, the physician must also be able to identify important information once in the record. Each record must contain a great deal of detail regarding what was studied, who the physician was, what tests were run, what the test methodology was, who conducted the tests, and so on and so forth. However, it was clear in the observation sessions that some information was more important that other information, as a good deal of an individual chart is used for billing purposes. In order to more quickly identify pertinent information, free-text entry should stand out from automatically-generated textual information, which is created from list selections of symptoms and other criteria.

Colors, labels, distinguishing font characteristics, images, icons, etcetera should be employed to make salient the more important aspects of a record, and particularly those indications written directly by the physician and those that indicate the diagnosis and course of treatment. This would help to provide a quick and easily
accessible overview to point out which details are the most significant. Additionally, creating headings, summaries, and dividing the information up into related groups and columns would assist in scanning the document more quickly for details.

5.2.3 Addressing Record Macrostructure

There are far too many types of records to create one consistent record macrostructure. For instance, an endoscopy record will be quite different than an emergency department visit for a broken wrist. However, one consistent aspect of records, and the two most important sections in every record type, are the sections in which Impressions and Recommendations are summarized. These sections together essentially form an abstract of the visit, providing a summary of the most important findings or results from the visit and what the course of treatment ought to include.

While no overall schema can be applied to disparate records, there could be a general schema that focuses on these two sections being at the top of every record, rather than at the bottom, where they are typically located. As these give an overview of the most important information, they could function through a hybrid form of IV to allow fast access to data by zooming, filtering, and getting details, which could be presented through a variety of data structures.

For instance, in Figure 6, the first two impressions listed could be linked to data types that provide further details. The first impression indicates “Atrial fibrillation with a rapid ventricular rate.” Temporal data to support this impression could be linked showing the actual EKG wherein the impression was founded. The second impression indicates “Chronic obstructive pulmonary disease with exacerbation.” Two-dimensional data in the form of a chest x-ray could then be linked to provide further details for reference.

Beyond that, multi-dimension forms of IV could show relational or statistical data to see how a lung x-ray and heart-rate are related in the patient’s condition over several visits. Or perhaps a network of data could be constructed to show complex data relationships through links or nodes. This would give a more comprehensive macrostructure by linking pertinent data throughout records, rather than focusing on data from visit to visit, which could potentially be a great aid in clinical decision making.

6. CONCLUSIONS

Overall, the physicians that participated agreed with all the areas of recommendations for improving usability. Further work focusing on interactive, higher quality prototypes would need to be conducted to create a redesign that could be adequately tested for usability. However, through the participatory design and feedback session, it was clear that most changes based on HCI principles were considered valuable improvements that would save time and hopefully limit errors. Less clear, however, was the impact that changes utilizing IV would have on analyzing and synthesizing complex data.

While the physicians felt comfortable with the idea of making things more visual, and agreed that visual changes in the Tracking Board were clearly more helpful, the conceptual ideas for making EMR’s more visual were harder to evaluate. The physicians agreed that benefits of IV such as making complex information easier to understand and manage, making subtle aspects easier to notice, seeing cause and effect relationships more clearly, and preventing information overload were undeniably very important; nevertheless, the complexity of medical data make it difficult to analyze how best to implement IV. During the participatory design and feedback session, both physicians were very enthusiastic about the concept of sorting and categorizing records through a tree structure to understand which records to click into, and they were also very much in agreement on putting Impressions and Recommendations prominently at the top of records with either direct links to or mashups containing important referential data sources like x-rays or EKGs, etc.

The physicians were intrigued by the ideas of multidimensional displays of information and networked data structures within the records that would relate pertinent information throughout records, however the complexity of this type of data structure and how it could be visualized is something that requires much further investigation into relationships between data types and the tasks a physician might want to perform in analyzing the data.
7. FUTURE DIRECTIONS

Future work in this area ought to focus on continual improvement of usability in healthcare interfaces and applying better testing and standards. None of the physicians in the observed department had consulted with administration or the vendor prior to choosing the current system, and it is not clear what the testing procedures and standards are in the development of emergency department information systems. As these types of systems are adopted rapidly over the next few years, standards need to be in place for usability just as much as for interoperability and productivity, which are much more heavily focused on as of now. Furthermore, usability must be analyzed in full context, which includes taking into account interruptions, handoffs and transitions between physicians and other medical staff, and coordination of care with other departments and hospitals.

Additionally, with the type of complex data that must be synthesized and analyzed quickly in an emergency medicine setting, it seems that information visualization could provide great benefits in reducing time and error while improving diagnoses and clinical decision making processes. So it seems the development of future healthcare information systems could definitely benefit from further evaluating the ways tasks and data types can form novel, hybrid structures for accessing and relating complex patient data. As paradigms shift in forms of interaction, new areas for exploration abound and IV techniques should be a part of that exploration.

8. REFERENCES


